

# (12) UK Patent Application (19) GB (11) 2 385 747 (13) A

(43) Date of A Publication 27.08.2003

<p>(21) Application No 0204093.9</p> <p>(22) Date of Filing 21.02.2002</p>	<p>(51) INT CL<sup>7</sup> H04B 1/713</p>
<p>(71) Applicant(s) Toshiba Research Europe Limited (Incorporated in the United Kingdom) Telecommunications Research Laboratory, 32 Queen Square, BRISTOL, BS1 4ND, United Kingdom</p> <p>(72) Inventor(s) Russell John Haines Michael Philip Fitton Timothy David Farnham</p> <p>(74) Agent and/or Address for Service Brookes Batchellor 102-108 Clerkenwell Road, LONDON, EC1M 5SA, United Kingdom</p>	<p>(52) UK CL (Edition V ) H4L LBSF LRRMR L215</p> <p>(56) Documents Cited GB 2365710 A GB 2350976 A DE 003415032 A1 US 5848095 A US 5541954 A US 4716573 A</p> <p>(58) Field of Search UK CL (Edition T ) H4L LBSF LDXL LFMA LFMX LFND LRNMT LRRMD LRRMR L215 INT CL<sup>7</sup> H04B 1/713 1/74 Other:</p>

(54) Abstract Title  
**Channel management in adaptive hopping scheme**

(57) An adaptive frequency hopping scheme for use in a predetermined spectrum of communication channels, for example, Bluetooth (RTM), comprising the steps of setting a monitoring period for each channel while it is in use, detecting the number of damaged or lost transmissions within the monitoring period, marking the channel as "bad" if the detected number is greater than a first predetermined number and then allocating an alternative channel of the spectrum for use. The process may be iterated by using an increasing wait time, before re-checking the "bad" channel, with more severe signal quality criteria. If the signal quality is found to be adequate, the status of the "bad" channel is changed to "good" and the channel is re-instated for use into the spectrum of available channels.

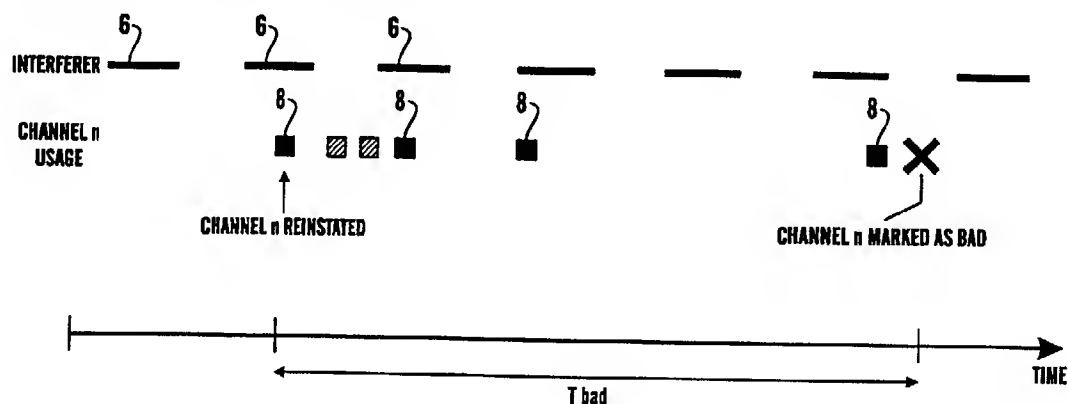


Fig.2

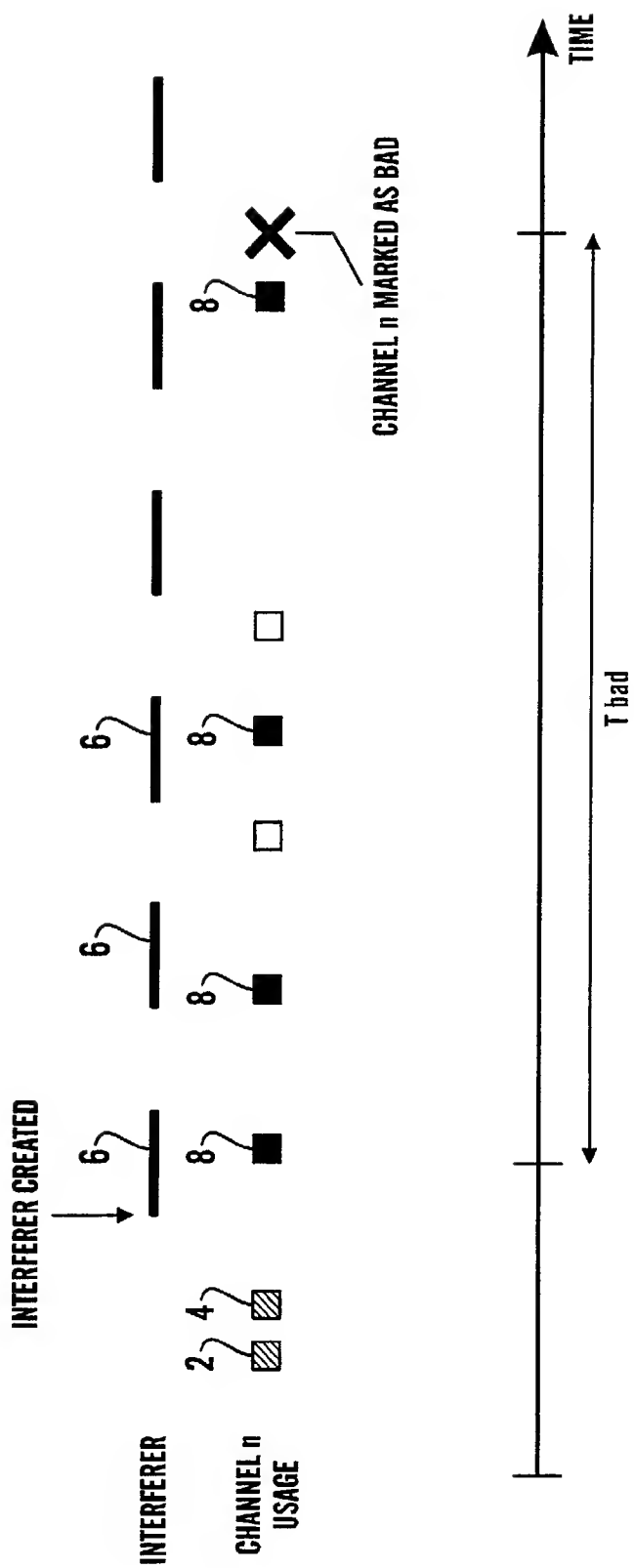


Fig. 1

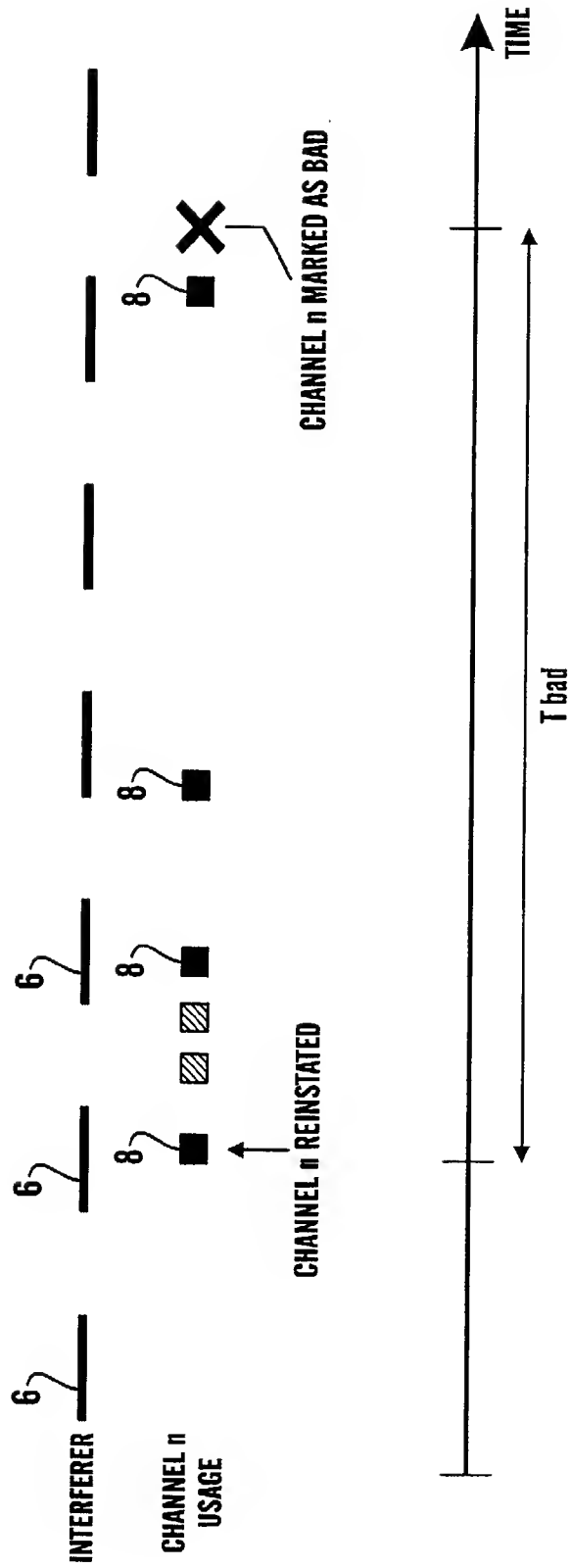


Fig.2

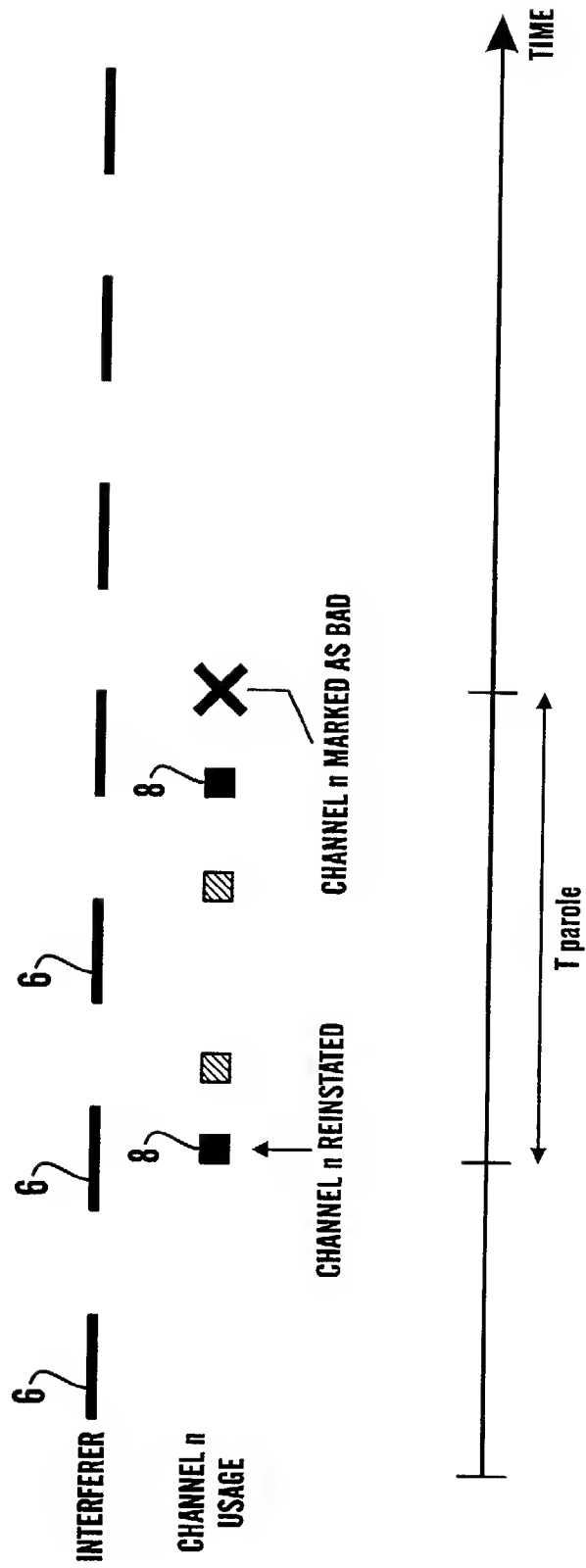


Fig.3



Fig. 4a

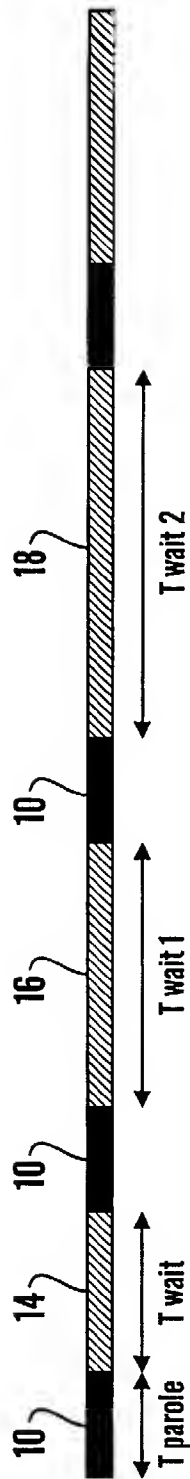


Fig. 4b

"Channel Management in Adaptive Hopping Schemes"

This invention relates to wireless communication systems employing adaptive  
5 frequency hopping schemes, in which noisy channels can be substituted by good  
channels, until such time as the interference on the noisy channels reduces to an  
acceptable level.

It is known to utilise adaptive frequency hopping, in order to maintain the best  
possible quality of reception over communication channels, by adapting to an unknown  
10 or varying spectral environment in a channel, for example as described in U.S.  
6,084,919 (Motorola).

It has also been proposed to provide a "ranking system" in which channels are  
listed in order of quality, so that a channel can move down the ranking if its quality  
decreases, or up the ranking if its quality increases (U.S. 5,448,750)

15 Accordingly, it is possible to reduce the usage of a particular channel, relative to  
the usage of other available channels, if its quality deteriorates, and conversely, the  
channel can be reinstated once it has been detected as being clear.

The present invention seeks to provide an improved method of determining the  
quality of channels, in order to decide how frequently they should be used, and in  
20 addition, to provide a method of controlling the manner in which channels are reinstated  
for use, in accordance with their past performance history.

According to one aspect of the present invention, there is provided an adaptive  
frequency hopping scheme for use in a predetermined spectrum of communication  
channels, comprising the steps of setting a monitoring period for each channel while it is  
25 in use, detecting the number of damaged or lost transmissions within the monitoring  
period, marking the channel as "bad" if the detected number is greater than a first  
predetermined number and then using an alternative channel of the spectrum.

Preferably, the channel is marked as bad as soon as the predetermined number of damaged or lost transmissions has been exceeded, even if this occurs well inside the preset monitoring period.

5        Preferably, once a channel has been marked as "bad" it may be reinstated after a suitable interval, after which its performance will continue to be monitored, either in accordance with the same parameters as previously, or preferably, in accordance with a stricter set of criteria, i.e. may be placed in a "suspect" category.

10        Whilst channel is categorised as "suspect", its performance may be regarded as unsatisfactory, unless its performance has improved, e.g. as soon as a smaller number of transmissions have been lost or damaged within a monitoring period. Preferably, this monitoring time period is shorter, for channels in the suspect category, than for those whose performance is regarded as satisfactory.

15        When a channel has been categorised as "suspect", it may be reinstated after a fixed period, but in accordance with a preferred embodiment of the invention, each time a channel is reinstated after having been treated as suspect, the period before reinstatement is increased. It will be appreciated that this preferred reinstatement scheme avoids the system from wasting the effort of frequently reinstating and rejecting a suspect channel, and thereby losing system throughput.

20        A system of this kind may be employed in various contexts, such as cellphone systems, operating in conjunction with fixed base stations, or "Bluetooth" type systems involving "ad-hoc" networking between a mix of fixed and mobile devices.

Work is underway within the Bluetooth Special Interest Group (SIG) to improve the basic Bluetooth system. There are several working groups within the SIG working on different improvements to the basic Bluetooth 1.1 standard.

25        One of these is the coexistence working group, which is concerned with the mutual coexistence within the 2.4 GHz licence exempt band in which Bluetooth operates along with other systems such as IEEE802.11b WiFi systems and baby alarms.

Bluetooth conventionally uses frequency hopping to spread energy around the band, but this is a random hopping process that does not take into account the effects of and on other users of the band.

The proposed solution for the improved Bluetooth system is to adopt adaptive  
5 frequency hopping, i.e. to not just pseudo-randomly hop through the 79 channels in the band, but to identify and avoid channels in which other systems are operating. Clearly, these competing systems may not continue to interfere throughout the lifetime of the Bluetooth piconet.

The system of the present invention may be extended to any system adopting an  
10 Adaptive Frequency Hopping Scheme.

Firstly, whilst a bad channel may appear to be clear, the interferer may be periodic, or may have only temporarily stopped, i.e. the probability of a bad channel reoffending is high. With this in mind reinstated channels should be considered suspect or "on parole" when first reinstated. Whilst on parole the penalties associated with any lost packets on  
15 that channel would be more severe, i.e. whereas a "good" channel may have to lose several packets over a period of time before being considered for replacement, a paroled channel would only have to lose a small number of packets before being replaced again.

The penalties incurred whilst on parole may be increased with each subsequent  
20 reoffence; i.e. the number of bad transmissions within a period needed for the channel to be rejected again may be reduced, or the time period within which these bad transmissions must be observed may be extended. This is so that a channel repeatedly susceptible to interference can be rejected even more quickly.

Secondly, if a reinstated channel fails its probation period, a back-off scheme may  
25 be adopted so as to further penalise that channel. One preferred scheme is an exponential back-off scheme, where successive reinstatements are spaced further and further apart (e.g. it is tried again after 5s, then 10s, then 20s ...etc.) In this way if a



channel is not getting any better, it is used less and less often before eventually (perhaps) being completely abandoned for the duration of the session.

However, a channel may redeem itself (if, for example, a period passes with no bad transmissions, or there are a pre-requisite number of good transmissions), or it is otherwise established that it is clear. In that case it ceases to be on parole, and is treated in the same way as any other "good" channel.

This back-off scheme may be applied either in a case where channels are reinstated blindly after a period of time (with no attempt to verify that the channel is now free from interference) or where they are tested a number of times before reinstatement (perhaps by transmitting "probe" packets on the channel to test for successful transmission).

Some embodiments of the invention will now be described by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram illustrating an initial channel quality assessment process;

Figure 2 is a diagram illustrating a channel reinstatement process;

Figure 3 is a diagram illustrating quality assessment for a reinstated but "suspect" channel; and

Figure 4 is a diagram illustrating channel assessment including a reinstatement "back-off" scheme.

Referring to Figure 1, successive transmissions along a channel are illustrated by blocks 2, 4 etc, whilst a source of periodic interference is indicated by bars 6. In the example shown, the channel is initially monitored for a period "T<sub>bad</sub>" shown on the time axis, during which four bad transmissions are detected, which are indicated by the dark shaded transmission blocks 8 in the drawing. As shown, the fourth bad transmissions occurs just before the end of the monitoring period, which is a "worst case scenario", but

in practice, the channel might be marked as "bad" as soon as a certain proportion of transmissions (as illustrated, four out of six) are detected as being bad.

Figure 2 illustrates a standard "reinstatement" scheme, in which, once again, the channel is monitored for a period " $T_{bad}$ ", and is again marked bad as a result of the  
5 detection of four lost or damaged transmissions, indicated by the dark blocks 8, out of a total of six transmissions.

Clearly, the "standard" reinstatement scheme could involve a considerable number of wasted transmissions, if the interference pattern indicated at 6 were to persist. According, as illustrated in Figure 3, when a channel has previously been marked as  
10 "suspect", it is preferable placed in a "on parole" category in which it is subject to stricter criteria for being marked as "bad". As illustrated in Figure 3, it will be seen that with the interference 6 persisting, bad transmissions 8 will continue to occur as before, but since the channel has been placed in the "suspect" category, the monitoring period " $T_{parole}$ " is now of reduced length, and the channel is marked as bad as soon as two lost or  
15 damaged transmissions have been detected.

In the above described example, the channel is reinstated after a fixed period, which can be set simply by a timer. Alternatively, it is envisaged that dummy packets may be transmitted on the channel during the "wait" period, in order to verify lack of interference.

20 Additionally, instead of being reinstated after a fixed period, the "waiting period" may be successively increased, for a channel which is repeatedly found to be bad. These two possibilities are illustrated diagrammatically in Figure 4, in which Figure 4a illustrates successive "parole" periods 10 which are separated by successive "wait" periods 12, during which the channel quality may be reassessed, with each of the  
25 periods 12 being equal in length. Alternatively, as illustrated in Figure 4b, successive wait periods 14, 16, 18 are increased in length, each time the channel has failed during its "parole" period 10. In this way, it is possible to avoid the wastage of resources

inherent in the kind of scheme illustrated in Figure 4a, in which the “bad” channel can be utilised too frequently.

## CLAIMS

1. An adaptive frequency hopping scheme for use in a predetermined spectrum of communication channels, comprising the steps of setting a monitoring period for each channel while it is in use, detecting the number of damaged or lost transmissions within the monitoring period, marking the channel as "bad" if the detected number is greater than a first predetermined number and then using an alternative channel of the spectrum.
2. An adaptive frequency hopping scheme according to claim 1 in which a channel is marked "bad" as soon as the predetermined number of damaged or lost transmissions has been exceeded.
3. An adaptive frequency hopping scheme according to claim 1 or claim 2 in which a channel which has been marked as "bad" is reinstated for use after a predetermined waiting period.
4. An adaptive frequency hopping scheme according to claim 3 in which a reinstated channel is monitored in accordance with stricter criteria so that it will be marked as "bad" again more quickly unless its performance has improved.
5. An adaptive frequency hopping scheme according to claim 4 in which a reinstated channel is marked as bad as soon as the number of damaged or lost transmissions exceeds a second predetermined number which is less than the first predetermined number.
6. An adaptive frequency hopping scheme according to claim 4 or claim 5 in which the monitoring period is shortened for a reinstated channel.
7. An adaptive frequency hopping scheme according to any one of claims 4 or claim 6 in which the waiting period is progressively increased for a channel which is repeatedly marked as bad.

8. An adaptive frequency hopping scheme according to any one of claims 3 to 7 in which dummy transmissions are made on each "bad" channel during the waiting period in order to determine whether its performance is satisfactory.



INVESTOR IN PEOPLE

Application No: GB 0204093.9  
Claims searched: 1

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Examiner: Dr Jan Miasik  
Date of search: 5 September 2002

## Patents Act 1977 Search Report under Section 17

### Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK Cl (Ed.T): H4L(LBSF, LFMA, LFMX, LRNMT, LDXX, LFND, LRRMD, LRRMR L215)  
Int Cl (Ed.7): H04B1/(713, 74)  
Other: Online: EPODOC, WPI, JAPIO

### Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2365710 A (Vtech Communications Ltd.): see whole document, particularly p. 4, line 29 - p. 5, line 8 and abstract	1 & 2
X	GB 2350976 A (Adaptive Broadband Ltd.): see whole document, particularly p. 2, line 2 - p. 3, line 14 and abstract	1 & 2
X	US 5848095 (WAVTrace Inc.): see whole document, particularly col. 6, lines 1-12	1 & 2
X	US 5541954 (Sanyo Electric Co., Ltd.): see whole document, particularly col. 4, lines 49-58	1 & 2
X	US 4716573 (Telefonaktiebolaget LM Ericsson): see whole document	1-3 & 8
X	DE 3415032 A1 (Siemens Ltd./Fedkom Stelsels): see abstract	1-3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.